CENTRAL INTELLIGENCE AGENCY

# INFORMATION REPORT



SECRET
SECURITY INFORMATION

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## ANGLE OF ATTACK DATA USED FOR VARIOUS MISSILES AT OSTASHKOV

### General

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1. For long range rockets the dependence on $\alpha$ was neglected in the first force equation. [redacted] That is, the thrust was calculated with $S$ instead of $S \cos \alpha$ and $C_W$ for $\alpha = 0$ was used. In some cases, as in the R-12, the error resulting from this simplification was determined by means of a perturbation calculation. [redacted]

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2. In contrast to the long range missiles, the dependence of $C_W$ on $\alpha$ and the rudder deflection angle $\eta$ was taken into account in the trajectory calculations of the Wasserfall. $C_W$ was applied in the following form:

$$C_W = C_{W_0} + C_W^{(1)} \alpha^2 + C_W^{(2)} \eta^2 + C_W^{(3)} \alpha \eta$$

As a result of this consideration, the two force equations and the moment equation, which were now connected, had to be solved simultaneously. [redacted] The dependence of $C_W$ on $\alpha$ and $\eta$ resulted in a considerable increase in the air resistance.

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(Note: Washington Distribution Indicated By "X"; Field Distribution By "#".)

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Comparing the vertical ascent with a sloped, inclined path, we find the following: In the vertical ascent, the loss of speed caused by gravity

$$V_{mg} = \int_0^t g\,dt \approx gt$$

is great in comparison with the loss of speed resulting from air resistance.

$$V_w = \int_0^t \frac{W}{m}\,dt = \frac{\rho_0}{2} F \int_0^t \frac{1}{m} \frac{\rho}{\rho_0} c_w V^2 dt$$

In a sloped path the inverse is true and $V_w$ is large in comparison with

$$V_{mg \sin\gamma} = \int_0^t g \sin\gamma\,dt$$

The end result is that the cutoff speeds in both the vertical ascent and the inclined path do not differ greatly.

Variation of the Angle of Attack in the Wasserfall

3. The variation of the angle of attack in the Wasserfall depends on the approach of the target. In target approaches in the direction toward the launching site, the variation of the angle of attack is as follows:

   At the beginning of the deflection, controlled by the calculator, $\alpha$ becomes negative and assumed values between -10 degrees and -15 degrees. Then, $\alpha$ becomes increasingly smaller and upon entering the speed of sound has a value somewhere between 2 and 4 degrees (either + or -). When on the pursuit course, $\alpha$ assumes positive values. Should the impact point lie ahead of the location of the launching site, $\alpha$ will remain positive until the end. In fighting a target, that is, in a receding flight from the launching site, it is conceivable that $\alpha$ will again assume negative values, for example, during a nose dive of the target shortly before the impact. [redacted] such cases were not calculated in Ostashkov. The calculations described above were only for a vertical plane which included the launching site.

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Example of a Trajectory of Wasserfall and the Variation of the Angle of Attack

Approach of Target

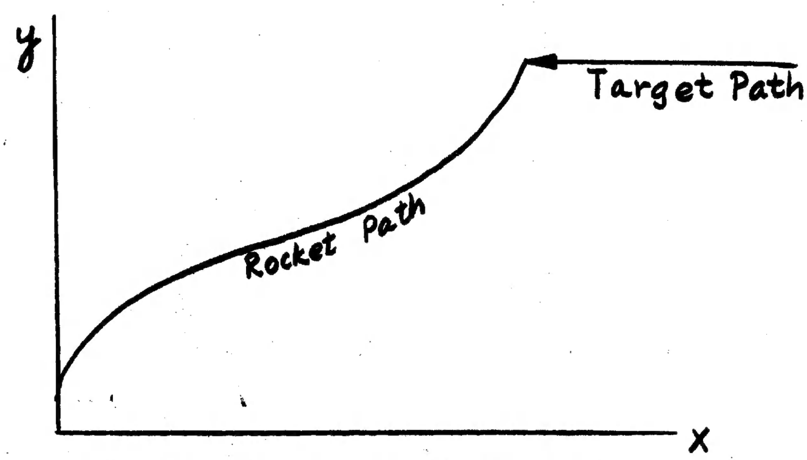


Figure 1. Typical trajectory of Wasserfall.

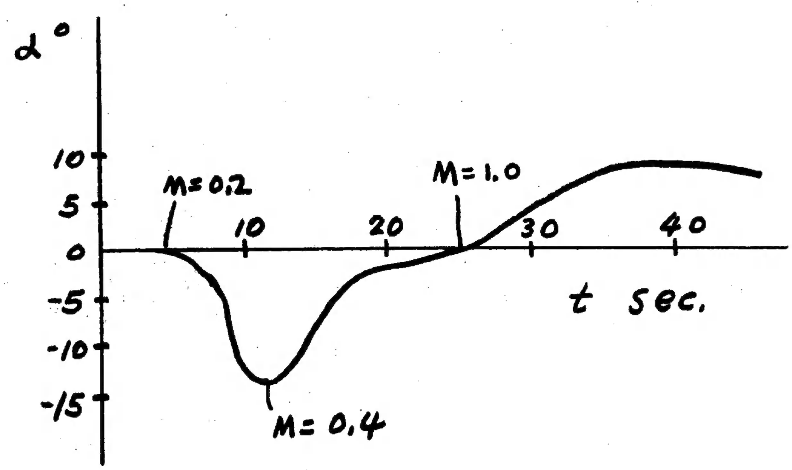


Figure 2. Angle of attack variation for Wasserfall.

(Note: Values shown on this and following figures are approximate only.)

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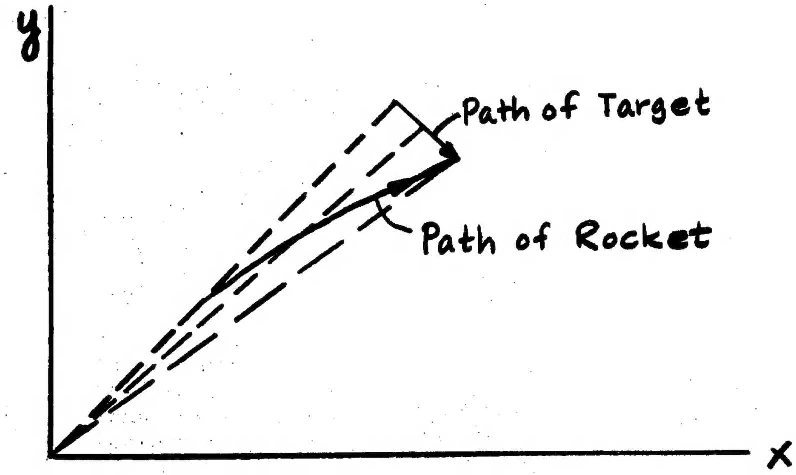


**Figure 3.** Example of Wasserfall trajectory when angle of attack could assume small negative values near impact with target.

## Variation of the Angle of Attack in the A-4

4. The variation of the angle of attack in the A-4 trajectory for the firings performed in Kapustin Yar was theoretically as follows:

> After four seconds of vertical ascent there is the deflection from the vertical and $\alpha$ assumes negative values up to approximately eight degrees. [redacted] not certain of the exact values. 50X1-HUM Then there occurs a recession towards zero, and zero is reached between Mach numbers of .8 to 1.2. This last requirement was ascertained by determining the simulator deflection angle $\gamma$ from the differential equation:
>
> $$V\dot{\gamma} + g\cos\gamma = 0$$
>
> Past Mach No. 1.2 there occurs again a pronounced bending of the trajectory, that is a negative angle of attack, followed by transition to positive values, reaching as high as approximately five degrees.

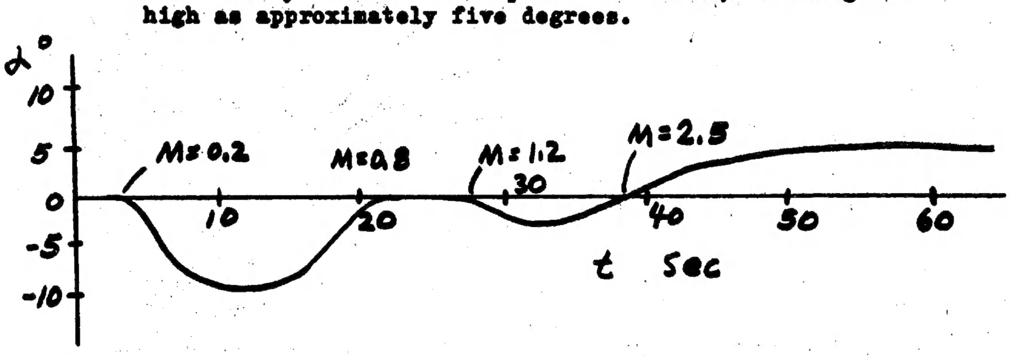


**Figure 4.** Approximate course of the angle of attack for A-4 trajectory.

During the analysis of the A-4 firings it was determined that at the time of passage through the sound speed, angles of attack of approximately two degrees occurred. The thrust during these firing tests was higher than had been assumed during the trajectory calculations.

**Variation of the Angle of Attack in the R-10**

5. The variation of the angle of attack in the R-10 was similar in principle to the A-4. On the last section of flight, which in contradistinction to the A-4 was a straight line, angles of incidence occurred which were larger than those obtained in the A-4.

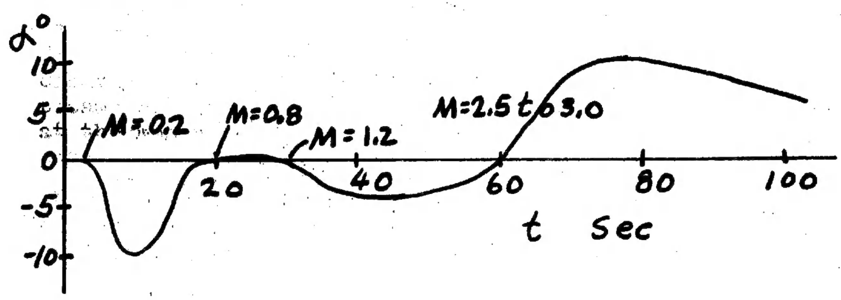


Figure 5. Approximate course of the angle of attack for the R-10

**Variation in the Angle of Attack in the R-14**

6. The variation of the angle of attack in the R-14 is distinguished from the A-4 and the R-10 in the following manner. As a result of the slow initial speed, only a very small angle of incidence was required for approximately two seconds for the deflection from the vertical ascent. Thereupon, the path sloped itself sufficiently under the gravity component, and the angle of incidence became equal to zero. Only upon aligning the axis of the missile at the moment of entering the straight final path of the powered path was a positive angle of incidence required.

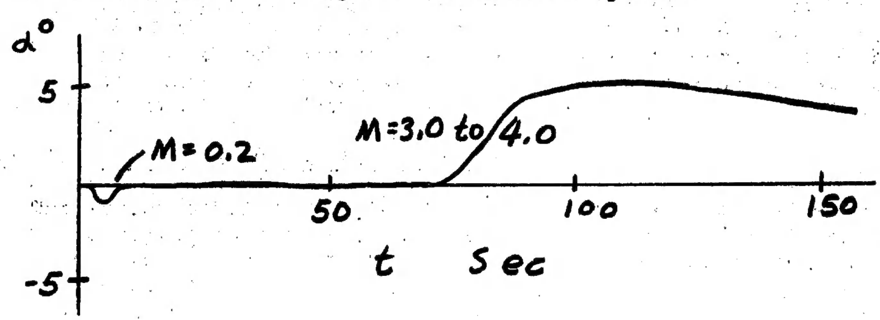


Figure 6. Approximate course of the angle of attack in the R-14

(Note: It is possible that the positive attack angle during the final phases of the trajectory was somewhat larger than shown.)

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**Variation of the Angle of Attack in the R-113**

7. The variation of the angle of attack in the R-113 is similar to the Wasserfall, dependent on the target approach. The function f (r,R), which determined the deflection, did not have the characteristic of causing a major decrease of the angle of attack when passing through the sound barrier. [redacted] 50X1-HUM

**ADDITIONAL DATA CONCERNING THE WASSERFALL UTILIZED AT OSTASHKOV**

**General**

8. [redacted] 50X1-HUM the combustion period was 46 seconds, [redacted] the thrust was approximately eight tons (after the jet rudder vane losses were deducted), and [redacted] the launching weight less than four tons. 50X1-HUM This results in a specific thrust acceleration of $\sigma = 5/G \approx 2$. The maximum speed was approximately 800 meters per second at an altitude of approximately 12-15 kilometers. The warhead weighed 250 kilograms. [redacted] the path calculations performed in Ostashkov [redacted] considered only straight horizontal target approaches with constant speed. Such a target movement is determined by the equation: 50X1-HUM

$$Ctg\,\Gamma_z = Ctg\,\Gamma_{z,0} - \frac{V}{H}t$$

where $\Gamma_z$ = angle of elevation of the target, v = the speed of the target, H = height of the target, and t = time. The value .02 $sec^{-1}$ was generally selected for the parameter v/H. This corresponds to a speed of 200 meters per second at an elevation of approximately 10 kilometers. Occasionally, however, variations of this value were considered (between 0.01 and 0.04).

9. Assumptions concerning the maximum safe-load factor for planes and the missile were not considered. In simple approaches (straight line, horizontal, and with constant speed) there occurred cases where the missile could not follow the target. The reason was not that the load factor of the missile was too large, but rather that the maximum rudder deflection of 25 degrees was insufficient to develop the angle of attack required for the trajectory, although that angle was on the whole not very large. The reason for the difficulty was that the distance between pressure center and gravity center was too great and, therefore, the moment required was too large. [redacted] 50X1-HUM

10. [redacted] no positive recommendations for the improvement of the German Wasserfall missile were made by the German engineers at Ostashkov. The criticism of the ballistic section consisted of pointing out the large inertia of the Wasserfall and the often-encountered unfavorable method of deflection of the rocket with the late beginning of the target pursuit path. As far as improvement of Wasserfall is concerned, it is possible to regard the whole R-113 as such. Considerations made in reference to the dynamic behavior of the missile are not known [redacted] 50X1-HUM

[redacted] 50X1-HUM

**The Target Pursuit Process for the Wasserfall**

11. The Wasserfall calculations in Ostashkov from the entry into the pursuit curve up to the impact were carried out according to the pursuit process, that is, the three point path [redacted] Examinations of the dog-curve pursuit paths were not made especially for Wasserfall, although some limited work was done on this type of pursuit path. Parallax calculators for the Wasserfall were not considered in Ostashkov. 50X1-HUM

(Notation: Small Greek letters refer to the missile. Large Greek letters refer to the target (plane). Angles for the missile: $\gamma$ = trajectory angle of inclination; $\Gamma$ = angle of elevation. Angles for the Target: $\gamma_z$ = trajectory angle of inclination; $\Gamma_z$ = angle of elevation.)

Requirement for the Target Pursuit ( 3 point trajectory):

$$(1) \qquad \Gamma = \Gamma_z$$

Of interest is the examination of the safe-load factor, defined as a quotient of lift/weight:

$$(2) \qquad \eta = \frac{qF \frac{\partial c_a}{\partial \alpha} \alpha}{G}$$

Instead of this, it is often required to examine the value:

$$(3) \qquad \frac{V\dot{\gamma}}{g} \qquad \text{(transverse acceleration)}$$

This value distinguishes itself from the safe-load factor primarily because of the gravity component cos $\gamma$, which taken as an absolute value remains smaller than 1; and the thrust component $S\alpha/G$, which acts in the same sense as n (since $S_\alpha$ and $qF\frac{\partial c_a}{\partial \alpha}\alpha$ have the same sign). [redacted] 50X1-HUM

[redacted] The motion of the target and the approximate missile speed are given by the first force equation [redacted] It is then possible to obtain the approximate values of the safe-load factor in the following manner: Between the trajectory angle of inclination and the angle of elevation exist the following relationships:

$$V \sin(\gamma - \Gamma) = r\dot{\Gamma}$$

$$V \cos(\gamma - \Gamma) = \dot{r}$$

[redacted] 50X1-HUM

(where r is the distance between launching station and missile).

From this, by differentiation, the following exact formula for the value of $V\dot{\gamma}$ is: 50X1-HUM

$$(4) \qquad V\dot{\gamma} = \left(2V - \frac{r\dot{V}}{\dot{r}}\right)\dot{\Gamma} + \frac{rV}{\dot{r}}\ddot{\Gamma}$$

[redacted]

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In many cases the value of v $\dot{\gamma}$ is determined by the first term on the right side of (4), so that

(5) $v\dot{\gamma} \approx 2v\dot{\Gamma}$

(It is of course necessary in every case to check to what extent this simplification is permissible.)

Should (2) and (3) be equated, and using (5) we get,

(6) $n \approx \frac{2v}{g}\dot{\Gamma}$

In the case of the target pursuit approach, (3 point trajectory), we obtain from (1) and (6) the following:

(7) $n \approx \frac{2v}{g}\dot{\Gamma}_z$ (Since $\Gamma = \Gamma_z$ and $\dot{\Gamma} = \dot{\Gamma}_z$ )

The path of the rocket itself, can be obtained in the following manner by means of the target pursuit approach (if v is regarded as given);

For the distance r (missile to launching site) we have the differential equation

(8) $\dot{r} = \sqrt{v^2 - (r\dot{\Gamma}_z)^2}$

The trajectory coordinates are then obtained from:

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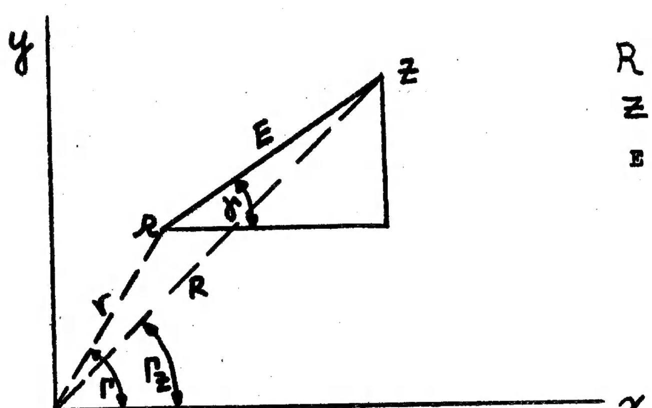
(9) $\begin{cases} x = r\cos\Gamma_z \\ y = r\sin\Gamma_z \end{cases}$

"Dog-Curve" Pursuit Method

12. Limited consideration was given to this method at Ostashkov.




R - Missile (x,y)

Z - Target (X,Y)

E - Distance between missile and target

Figure 7.

Conditions for the "Dog-Curve":

(10) $E \sin\gamma = Y - y$

(11) $E \cos\gamma = X - x$

Differentiation yields:

$$\dot{E}\sin\gamma + E\dot{\gamma}\cos\gamma = \dot{Y} - \dot{y} = V\sin\gamma_Z - V\sin\gamma$$

$$\dot{E}\cos\gamma - E\dot{\gamma}\sin\gamma = \dot{X} - \dot{x} = V\cos\gamma_Z - V\cos\gamma$$

(12) $E\dot{\gamma} = V\sin(\gamma_Z - \gamma)$

In straight-line horizontal flight of the target ($\gamma_Z = 0$ or 180 degrees)

(12) becomes (12') $E\dot{\gamma} = -V\sin\gamma$

The formulas (12) and (12') show that in the "Dog-Curve", the safe-load factor $\eta$ grows beyond all limits as the missile approaches the target. This is because of the fact that E approaches zero, while $\sin(\gamma_Z - \gamma)$ generally is not zero, hence $\dot{\gamma}$ and consequently $\frac{V\dot{\gamma}}{g}$ both become very large.